HIGH PERFORMANCE OF DIRECT TORQUE CONTROL FOR FIVE-PHASE INDUCTION MACHINE

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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Science in Electrical Engineering (Power Electronics and Drives).

Signature : .....

Name : .....

Date : .....

DECLARATION

I declare that this thesis entitled “High Performance of Direct Torque Control for Five-Phase Induction Machine” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

DEDICATION

To my parents,

supervisor Dr Auzani bin Jidin,

and friend Sundram Rahmalingam

for their support, care and patience.

ABSTRACT

In recent years, research on multiphase AC drives has received great attention due to its several advantages over three-phase drives such as reducing the amplitude and increasing the frequency of torque pulsations, reducing the rotor harmonic currents, reducing the current per phase without increasing the voltage per phase, and lowering the DC-link current harmonics and higher reliability. Until now, however, neither a circular flux operation nor a decagonal flux operation in formulating an optimal switching strategy has been proposed to achieve high-torque control performance of Direct Torque Control (DTC) of five-phase induction machines. A few previous studies on DTC of five-phase induction machine are limited to analyze the effects of selecting different voltage vectors on torque and flux control performances, which do not facilitate the DTC to obtain fast torque dynamic control, reduced torque ripple and switching frequency. This thesis proposes an optimal switching strategy of DTC of five-phase induction machines for high-performance torque control. By employing a five-phase inverter in the proposed method, it provides a greater number of voltage vectors as compared to that offered in the three-phase inverter which gives more options to select the most optimal voltage vectors. The analysis of effects of selecting different voltage vectors on DTC performances are carried out to identify the most optimal vectors that can be chosen to improve torque control performances for every operating condition. The identification is made with the aid of vector diagrams and some equations which are, equations of torque rate, slip angular frequency and current dynamic. Once the identification is done, all optimal vectors are tabulated into a look up table, and the optimal switching of vectors is accomplished by providing appropriate error status and flux sector into the look up table. The appropriate error status are obtained from the hysteresis comparators which are reponsible to determine proper amplitude of vectors and flux control operations, either to form the flux trajectory into a circular or a decagonal locus. The improvements of the proposed method are verified via simulation and experimental results. The results have shown that the torque ripple and switching frequency in the proposed method are greatly reduced about 50 % and 40 %, respectively from that obtained in the DTC with non-optimal switching strategyof five phase inverter, particularly at low-speed operation. The results have also showed that the proposed DTC with decagonal flux control produces a faster torque dynamic response than the non-optimal switching strategy of five phase inverter DTC. These improvements offered are important features for the electrical drive applications that require high-performance torque control and reduced switching losses or high-efficiency.

ABSTRAK

Sejak kebelakangan ini, kajian tentang pemacu AC berbilang fasa telah menerima perhatian yang tinggi disebabkan oleh banyak kelebihan yang dimilikinya berbanding dengan pemacu tiga fasa seperti pengurangan amplitud dan peningkatan frekuensi bagi denyutan dayakilas, pengurangan harmonik arus angker, pengurangan arus per fasa tanpa peningkatan voltan per fasa, dan pengurangan harmonik arus penghubung-DC dan keboleharapan yang lebih tinggi. Namun begitu, sehingga sekarang, tiada pengoperasian fluks membulat mahupun pengoperasian fluks dekagon dalam memformulasikan sebuah strategi pensuisan optimal dicadangkan untuk mencapai prestasi tinggi kawalan dayakilas bagi Kawalan Dayakilas Langsung (DTC) motor aruhan lima fasa. Segelintir kajian terdahulu tentang DTC motor aruhan lima fasa dihadkan untuk menganalisis kesan-kesan bagi pemilihan vektor voltan yang berlainan terhadap prestasi kawalan dayakilas dan fluks, yang mana tidak menyediakan DTC untuk mendapatkan kepantasan kawalan dayakilas dinamik, pengurangan riak dayakilas dan frekuensi pensuisan. Tesis ini mencadangkan sebuah strategi pensuisan yang optimal bagi pemacu DTC motor aruhan lima fasa untuk prestasi tinggi kawalan dayakilas. Dengan menggunakan sebuah penyongsang lima fasa dalam kaedah cadangan, ia menyediakan bilangan vektor voltan yang lebih banyak berbanding dengan yang ditawarkan dalam pemacu tiga fasa yang memberikan lebih banyak pilihan untuk memilih vektor voltan yang paling optimal. Analisa bagi kesan-kesan pemilihan voltan vektor yang berlainan terhadap prestasi DTC telah dilakukan untuk mengenalpasti voltan vector yang paling optimal yang boleh dipilih untuk menambahbaik prestasi kawalan dayakilas untuk setiap keadaan operasi. Pengenalpastian ini dilakukan dengan bantuan rajah vektor dan beberapa persamaan, iaitu persamaan kadar dayakilas, frekuensi sudut gelinciran dan arus dinamik. Apabila pengenalpastian ini telah dilakukan, kesemua vektor-vektor yang optimal telah dijadualkan ke dalam sebuah jadual carian, dan pensuisan vektor optimal disempurnakan dengan menyediakan status-status ralat yang bersesuaian dan sektor fluks ke dalam jadual carian tersebut. Status-status ralat yang besesuaian diperoleh daripada pembanding-pembanding histeresis yang bertanggungjawab menentukan amplitud vektor yang sesuai dan operasi kawalan fluks, sama ada untuk membentuk trajektori fluks dengan lokus membulat atau dekagon. Penambahbaikan-penambahbaikan bagi kaedah cadangan telah disahkan menerusi keputusan simulasi dan eksperimen. Keputusan tersebut telah menunjukkan bahawa riak dayakilas dan frekuensi pensuisan dengan kaedah cadangan dikurangkan sehingga 50 % dan 40 % daripada yang diperoleh dalam DTC dengan strategi pensuisan yang tidak optimal pemacu lima fasa, terutamanya pada operasi kelajuan rendah. Keputusan juga menunjukkan bahawa DTC cadangan dengan kawalan fluks dekagon menghasilkan sambutan dayakilas dinamik yang lebih cepat berbanding dengan DTC dengan strategi pensuisan yang tidak optimal pemacu lima fasa. Penambahbaikan-penambahbaikan ini merupakan ciri-ciri penting bagi aplikasi pemacuan elektrik yang memerlukan prestasi tinggi kawalan dayakilas dan pengurangan kehilangan pensuisan atau kecekapan yang tinggi.

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AC	-	Alternating Current
ADC	-	Analog Digital Converter
DAC		Digital Analog Converter
DC	-	Direct current
DSC	-	Direct Self Control
DSP	-	Digital Signal Processor
DT	-	Sampling period
DTC	-	Direct Torque Control
DTC1	-	Conventional DTC of Five Phase Inverter
DTC2	-	DTC with Optimal Voltage Vector Selection
DTC3	-	DTC with Decagonal Flux and Optimal Voltage Vector Selection
FPGA	-	Field Programmer Gate Array
FOC	-	Field Oriented Control
IGBT	-	Insulated gate bipolar transistor
IM	-	Induction Motor
LB	-	Lower band
SVM	-	Space vector modulated
UB	-	Upper band